International Journal of Modern Research in Engineering and Technology (IJMRET)
www.ijmret.org Volume 3 Issue 3 ǁ March 2018.

Effect of Gas Flaring on Corrosion of Metals
(Mild Steel and Copper)

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ABSTRACT: *The effect of gas flaring on the rate of corrosion of metals within Egi kingdom was investigated in this work. Surface water which has been exposed to gas flares, was taken from Ogbogu flow station in the Egi kingdom of Ogba/Egbema/Ndoni Local Government Area of Rivers State Nigeria, and was used for this experiment. The procedure involved soaking one set of the coupons of mild steel and copper in the water taken from the gas flow station and another set in distilled water and kept for 14 days; after which the metals were removed and weighed for weight loss as a result of the corrosive effect of both water. This process was repeated for 56 days and various data obtained was analyzed using empirical correlation. Matlab was used for computation and simulation. At day 42, corrosion rate for the flare zone water and distilled water were for* ***mild steel*** *3.332cm/days and 2.666cm/days and* ***copper*** *2.562cm/days and 2.277cm/days respectively. The result obtained showed a higher rate of corrosion for water taken from within the flare zone of Ogbogu Flow station than distilled water.*

Keywords: *Corrosion, Gas flaring, Metals, Distilled water, Matlab, mild steel, copper*

I. INTRODUCTION

The issue of gas flaring in Nigeria has become a topical one in view of the devastating effect gas flaring has in the socio-economic lives of the people in the affected areas. Historically, it is said that gas flaring is as old as oil production in Nigeria. Oil exploratory activities of oil companies in Nigeria have caused gas flaring resulting in loss of lives and properties in the affected communities where gas is flared (Abdulkareem, 2006).

In Nigeria, the oil and gas sector accounts for about 35 per cent of Gross Domestic Product (GDP), and petroleum exports revenue represents over 90 per cent of total exports revenue. Apart from petroleum, Nigeria's other natural resources include natural gas, tin, iron ore, coal, limestone, niobium, lead, zinc and arable land (Aigbedion, and Iyayi, 2007). Nigeria has one of the ten largest natural gas reserves in the world and roughly 50% of the deposits are discovered in association with oil. It possesses the largest deposits of natural gas in Africa, most of which are located in and around the Niger Delta region. Natural gas supply in Nigeria comes in two streams - gas in isolated wells (or non-associated gas), and gas discovered together with oil (associated gas) Ajugwo, (2013). These two sources exist in roughly equal proportions. While non-associated gas can be left underground until needed, associated gas is unavoidably lifted together with crude oil, and must either be harvested or disposed on-site as an unwanted by-product.

There is no specific legal framework that prohibits gas flaring in Nigeria inspite of the environmental problems associated with it (Arowolo *et al*, 2011). The existing law that appears to regulate gas flaring in Nigeria is not effective as it does not completely prohibit gas flaring but only provide monetary penalties for continued flaring of gas by oil companies in Nigeria (Effiong *et al*, 2012; Julius, 2011). Gas flaring is the burning of natural gas that is associated with crude oil when it is pumped up from the ground. This activity leads to corrosion which is a process, which converts a refined metal to a more chemically - stable form, such as its oxide, hydroxide or sulphide. Gas flaring results in the gradual destruction of materials (usually metals) by chemical reaction with the environment. In the most common use of the word, this means electrochemical oxidation of metal in reaction with an oxidant such as oxygen or sulphur (Breakell *et al.*, 2005).

In petroleum-producing areas where insufficient investment was made in infrastructure to utilize natural gas, flaring is employed to dispose of this associated gas. Gas flaring in oil rigs and wells contribute significantly to greenhouse gases in our atmosphere (Hassan *et al*, 2013; Ibitoye, 2014). These greenhouse gases in the atmosphere pollute the environment and the marine habitat. Flares are common because they are used industrially for quick disposal of continuous flow of excess gases and for disposal of large surge of gases in an emergency calls. Other disposal system in use include atmospheric discharge (venting) disposal to a lower pressure. The principal harmful substances that are discharged into the atmosphere when crude (solid fuels) or other substances that are combusted are:

carbon dioxide, carbon monoxide, hydrogen sulphide, sulphur dioxide, ammonia and fluoride compounds. Acid rain has been linked to the activities of gas flaring. This occurrence takes place when the discharged gases released during combustion comes in contact with matter/moisture in the atmosphere forming acid rain which are very corrosive to metals when they rain on them (Kindzierski, 2000; Nkwocha, 2010).

Corrosion can affect metals in a variety of ways depending on its nature and the precise environmental conditions prevailing. Therefore, in the process of gas flaring at high temperature, oxide of nitrogen in the atmospheric (mainly during geological activities) does not recycle by airy transfer. The flared gases and gaseous pollutants contributed to the distribution and deterioration of metallic properties as a result of corrosive action taking place (Amadi *et al*, 2009; Obia *et al*, 2011; Obia, 2010). Corrosion simply refers to the undesirable deterioration or degradation of metal components or metallic alloys. This is due to the reactions of the metals/environmental reaction which results to adverse consequences on the properties of the metals. Most metals corrode on contact with water (and moisture in the air), acids, bases, salts, oil, aggressive metal polishes and other solid and liquid chemicals. Metals will corrode when exposed to gaseous materials like acid vapours, formaldehyde gas, ammonia gas, and sulphur containing gases. Hence, any substance or environmental factor that causes disintegration of metals or any other material and subsequently corrodes the metals (in this case, rusting it), such is said to be corrosive, Obia, (2009). The environment can be polluted by hydrocarbon gases when some of the intermediate end products of petroleum processing plants are flared off upon production in the absence of demand (Ayoola, 2011; Ekpoh *et al* 2010, Manby, 1999).

II. MATERIALS AND METHODS

2.1 Materials

1. Two coupons of copper of size 30 x 50mm with thickness 2mm
2. Two coupons of mild steel of size 30 x 50mm with thickness 2mm
3. Water exposed to gas flaring from Ogbogu Gas Flow Station
4. Distilled water

2.1.1 Apparatus

Electric (digital) weighing balance, saw blade, and micrometer screw guage.

2.2 Experimental Procedures

Two (2) rectangular coupons of the two metals (copper and mild steel) whose initial weight were taken was soaked in distilled water and in the water from the flare zone and kept in the laboratory separately. The coupons were allowed for the period of 14 days (two weeks) before being removed from the water and weighed and the weight of each metal were recorded after which the various coupons were washed from the previous corrosion and soaked again. These processes were repeated for the period of 56 days.

2.3 Corrosion Rate Calculation

The rate of corrosion is related to the weight loss as:

$$C_R = \frac{\Delta m * 3.45 * 10^6}{A * \rho * t} \qquad (1)$$

where C_R = corrosion rate in (cm/day), A= cross sectional area of coupon in (cm^2), P = Density of coupon in (g/cm^3), Δm = weight loss in (g), T = period of exposure

III. RESULTS AND DISCUSSIONS

3.1 Analysis of Water from Flared Zone

p^H = 6.63,

Electrical conductivity ($\mu s/cm$) = 151,

Chloride ion, Cl^{-}, (mg/l) = 18.22,

Total hardness, (mg/l) = 600,

Total suspended solid (g/l) = 2.04,

Total dissolved solid (g/l) = 560,

Fe^{2+} (ppm) = nil,

Zn^{2+} (ppm) = 0.426,

Total heterotrophic bacteria, (cfl/ml) = $0.07*10^{4}$,

Total caliform bacteria, (mpn/index/100ml) = 0.10,

Facial caliform bacteria, (mpn/index/100ml) = $12.4*10^{1}$

3.2 Properties of Distilled Water

Electrical conductivity (μs/cm) = <50,

Chloride ion, Cl^{-}, (mg/l) = 250,

Total hardness, (mg/l) = 500,

Total suspended solid (g/l) = 2 to 5,

Total dissolved solid (g/l) = 500,

Fe^{2+} (ppm) = 0 to 0.30,

Zn^{2+} (ppm) = 3.0,

Total heterotrophic bacteria, (cfl/ml) = <100/100ml,

Total caliform bacteria, (mpn/index/100ml) = 0 to 2,

Facial caliform bacteria, (mpn/index/100ml) = nil

The results of the weight loss and the rate of corrosion of the different metals in the distilled water and water from flared zone (Ogbogu gas flow station) in the course of the experiment are as represented in Tables 1a,1b, 2a, 2b below.

3.3 Mild Steel

From Tables 1a, 1b and Figure 1 it can be seen that the corrosion rate in the distilled water and in flare zone water were highest within 14 days period. It was observed that the mild steel corroded faster with a higher corrosion rate in the flared zone water than in the distilled water. In both environments the corrosion rate dropped after 42 days.

Table 1(a): Corrosion Rate of Mild Steel soaked in Distilled Water

Period of exposure (days)	Length (cm)	Width (cm)	Thickness (cm)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (cm/days)
14	5	3	0.2	8.34	8.336	0.004	3.999
28	5			8.34	8.334	0.006	2.999
42	5			8.34	8.332	0.008	2.666
56	5			8.34	8.332	0.008	1.999

Table 1(b): Corrosion rate of Mild Steel soaked in water from flared zone (Ogbogu gas flow station)

Period of exposure (days)	Length (cm)	Width (cm)	Thickness (cm)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (cm/days)
14	5	3	0.2	8.86	8.854	0.006	5.998
28	5			8.86	8.852	0.008	3.999
42	5			8.86	8.850	0.010	3.332
56	5			8.86	8.850	0.010	2.499

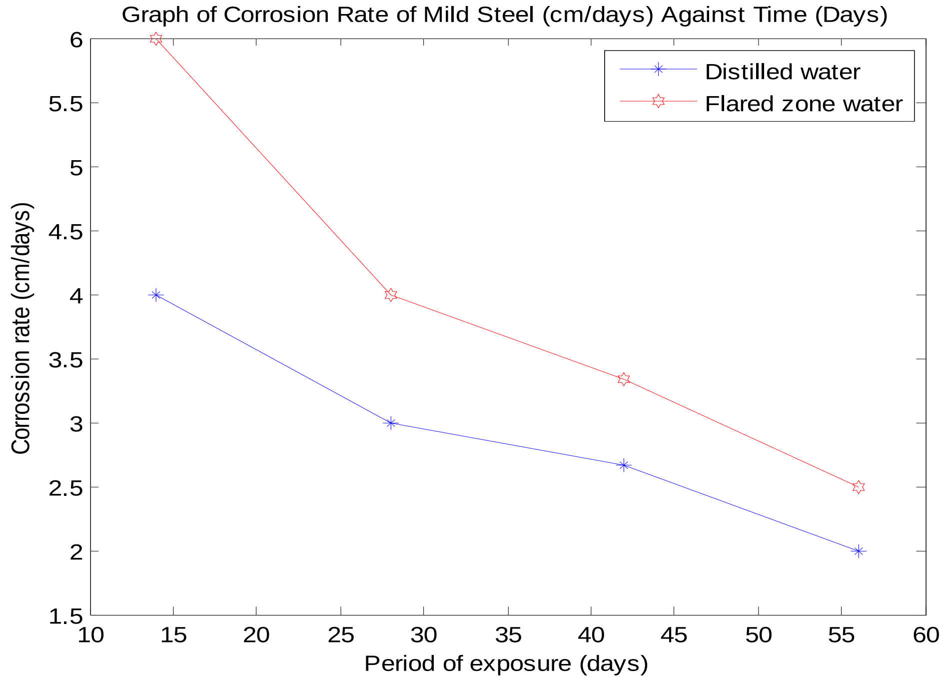

Figure 1: Corrosion rate of Mild Steel soaked in distilled water and water from flare zone (Ogbogu gas flow station)

3.4 Copper

From Tables 2a, 2b and Figure 2, it can be seen that the corrosion rate in the distilled water and in flared zone water were highest within the 14 days period. It was observed that the copper coupon corroded faster with a higher corrosion rate in the flare zone water than in the distilled water. In both environments the corrosion rate dropped after 42 days.

Table 2(a): Corrosion rate of Copper soaked in distilled water

Period of exposure (days)	Length (cm)	Width (cm)	Thickness (cm)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (cm/days)
14	5	3	0.2	13.10	13.097	0.003	2.562
28	5	3	0.2	13.10	13.095	0.005	2.135
42	5	3	0.2	13.10	13.092	0.008	2.277
56	5	3	0.2	13.10	13.092	0.008	1.708

Table 2(b): Corrosion rate of Copper soaked in water from flared zone (Ogbogu gas flow station)

Period of exposure (days)	Length (cm)	Width (cm)	Thickness (cm)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (cm/days)
14	5	3	0.2	12.55	12.554	0.005	4.270
28	5	3	0.2	12.55	12.544	0.006	2.562
42	5	3	0.2	12.55	12.541	0.009	2.562
56	5	3	0.2	12.55	12.541	0.009	1.922

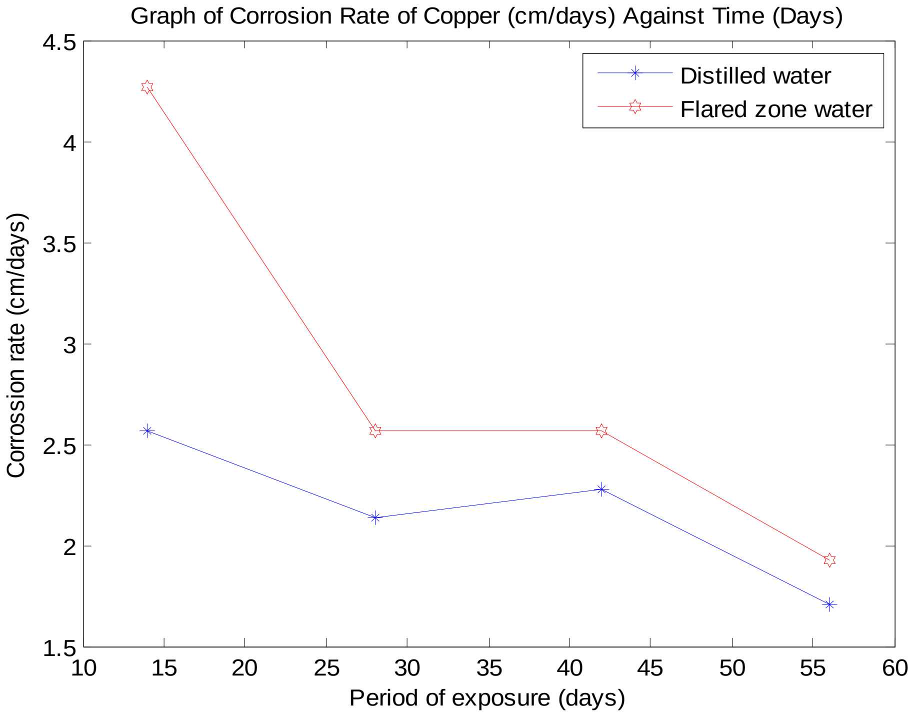

Figure 2: Corrosion rate of Copper soaked in distilled water and water from flare zone (Ogbogu gas flow station).

IV. Conclusion

The results from this work show that water from the flare zone of Ogbogu flow station has a higher corrosive effect on metals as a result of gas flaring which is mainly the primary cause of the high corrosive effect of the water on metals. The flared gas which is as a result of drilling activities going on within Egi area releases poisonous gases to the atmosphere, such as includes: Carbon dioxide (CO_2), Sulphur dioxide (SO_2), Hydrogen Sulphide (H_2S) etc which are very corrosive in nature. From the work, it is seen that rate of corrosion of copper and mild steel in the flared zone environment was higher than that in the distilled water environment. The result of the investigation reveals that gas flaring aids corrosion and is thus responsible for the high rate of corrosion of metals within the Egi kingdom of Rivers State, Nigeria.

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